SILVICULTURE OF BOTTOMLAND HARDWOOD FORESTS

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INTRODUCTION

Southern bottomland hardwoods are found on about 13 million ha of forest land in river bottoms, minor stream bottoms, and swamps from Virginia to east Texas (McKnight and Johnson, 1980). These diverse ecosystems support up to 80 commercially important tree species, each with unique biological requirements, silvical characteristics, and pattern of growth over time. Management of these diverse ecosystems is a complex task. In most southern bottomland hardwood forests, managers desire to maintain a viable oak (*Quercus* spp.) component for timber, wildlife, and biodiversity values, but regeneration of oak is difficult. However, most forests can be managed without an oak component and still yield multiple benefits.

Silvicultural systems integrate both regeneration and intermediate operations in an orderly process for managing forest stands (Clatterbuck and Meadows, 1993). Silvicultural practices are traditionally divided into two broad categories: even-aged and uneven-aged. The regeneration methods employed under even-aged silviculture include clearcutting, seed-tree, and shelterwood. Single-tree selection and group selection are regeneration methods used under uneven-aged silviculture (Table 1).

EVEN-AGED SILVICULTURAL SYSTEMS

Clearcutting

Regeneration by clearcutting favors the growth and development of moderately intolerant to intolerant species. In fact, clearcutting is the most proven and widely used method of successfully regenerating bottomland oak species in the South (Clatterbuck and Meadows, 1993). Clearcutting initially favors the growth and development of shade-intolerant, fast-growing, light-seeded species, such as sweetgum (*Liquidambar styraciflua*) and river birch (*Betula nigra*). During the early stages of development, the new stand is dominated by these pioneer species; oaks may be present in the stand, but are few in number and relatively inconspicuous (Meadows, 1994). However, studies on oak stand development have shown that bottomland oaks can eventually outgrow the more numerous and initially dominant sweetgum and form the dominant canopy of the mature stand (Johnson and Krinard, 1976, 1983, 1988; Clatterbuck and Hodges, 1988).

Successful regeneration of oak through clearcutting has three requirements: (1) presence of adequate oak advance reproduction in the stand prior to regeneration; (2) adequate sprouting potential of stumps from severed oak stems; and (3) cutting of all stems, both merchantable and non-merchantable, during the harvest operation.

Clearcut stands typically regenerate to shade-intolerant, fast-growing, light-seeded species if large oak advance reproduction (taller than 1 m) is lacking when the overstory is removed. Oak seedlings that become established after the harvest usually cannot compete with faster-growing species and will not comprise a major proportion of the total oak component in the mature stand.

Oak stump sprouts from severed stems are another source of oak reproduction in clearcut stands. Sprouts from severed trees less than 30 cm in diameter are an excellent source of regeneration because of their well-established root systems and vigorous growth potential (Janzen and Hodges, 1987; Hodges, 1989). Sprouting potential declines markedly in trees greater than 30 cm in diameter and large trees will not contribute significantly to the oak component of the new stand. Severed stems of oak seedlings and saplings present in the stand at the time of harvest will sprout vigorously. Creation of these oak "seedling sprouts" during the harvest operation should be encouraged.

The third requirement for successful oak regeneration through the clearcutting method is that all stems larger than seedlings must be cut or deadened during the harvest operation. This complete removal of stems from the existing stand will provide full sunlight to the forest floor and will enable the oak reproduction to successfully compete in the new stand.

Seed-tree

The seed-tree method of regeneration favors the establishment of light-seeded species, particularly sweetgum and yellow-poplar (*Liriodendron tulipifera*). However, retention of seed trees to successfully regenerate either sweetgum or yellow-poplar may not be necessary. Most sweetgum regeneration originates as stump sprouts or root suckers, whereas most yellow-poplar regeneration develops from seed stored in the forest floor rather than from freshly fallen seed from residual seed trees. Mechanical soil scarification may be necessary if the desired species requires bare mineral soil for establishment, as for eastern cottonwood (*Populus deltoides*) and black willow (*Salix nigra*). Retention of seed trees to establish new oak seedlings is unnecessary because most successful oak regeneration develops from advance reproduction or from stump sprouts (Johnson and Krinard, 1976).

Shelterwood

The shelterwood method is the most flexible of the even-aged regeneration methods, but also the most difficult to implement. It can provide for the development of heavy-seeded species, such as oaks (Loftis, 1990), but has produced highly variable results when used to regenerate southern bottomland oak species.

One of the keys to the successful use of the shelterwood method to regenerate oak is the intensity of the establishment cutting. Hodges (1989) concluded that heavy establishment cuts actually favor the development of fast-growing, shade-intolerant species rather than the oaks, whereas light cuts may encourage the development of less-desirable, shade-tolerant species commonly present in the midstory and understory of mature bottomland hardwood stands. In general, establishment cuttings that retain more than 12 m^2 ha^{-1} of basal area will tend to favor the development of shade-tolerant species. However, more research is needed to adequately define the optimum residual density necessary to successfully regenerate bottomland oak species through the shelterwood method.

One necessary modification of the classical shelterwood method is to supplement partial overstory removal with control of the midstory and understory prior to final harvest (Hodges and Janzen, 1987; Janzen and Hodges, 1987). Most southern bottomland hardwood stands have such dense, well-developed midstories and understories of shade-tolerant species that cutting in the overstory alone is insufficient to provide enough sunlight to the forest floor to promote the development of an adequate crop of oak advance reproduction prior to final harvest. Consequently, control of undesirable species in the midstory and understory, usually be chemical means, is essential for successful application of the shelterwood method to regenerate red oaks in southern bottomland hardwood forests.

Partial cuttings can also be designed to control species composition in such a way that seed sources of less-desirable species are reduced as much as feasible. Most partial cuttings, particularly those in older stands, should be performed with future regeneration in mind, such that cuttings are designed to create environmental conditions favorable for regeneration of desirable species and unfavorable for regeneration of undesirable species. In this way, partial cuttings performed late in the rotation should prepare the stand for regeneration, and render the need for a separate preparatory cutting unnecessary.

Single-tree selection

In the single-tree selection method of regeneration, single mature trees are removed from throughout the stand at regular intervals to create or maintain uneven-aged stands. Openings created through single-tree selection in southern bottomland hardwood stands range in size from 0.02 ha to 0.08 ha. Because these openings are small and do not allow much sunlight to the forest floor, this method favors the development of shade-tolerant species, few of which are commercially valuable. When single-tree selection is applied repeatedly, composition will gradually shift to less-valuable, more-tolerant species, such as sugarberry (*Celtis laevigata*), boxelder (*Acer negundo*), and elms (*Ulmus* spp.) (Johnson and Krinard, 1989).

Group selection

In the group selection method of regeneration, small groups of mature trees are removed from throughout the stand at regular intervals to create or maintain uneven-aged stands. Strict application of traditional group selection would result in openings of only 0.4 ha to 0.55 ha in area, as they would be limited to a diameter of twice the tree height (70 m to 75 m). The small openings created usually fail to allow sufficient light to reach the forest floor for satisfactory establishment and development of shade-intolerant species, such as most bottomland oaks (Clatterbuck and Meadows, 1993), resulting in stands dominated by low-value, shade-tolerant species.

Patch cutting, a combination of uneven-aged (group selection) and even-aged (clearcutting) silviculture, designed to create larger openings of 1 ha to 2 ha, has been successfully used by many forest managers to produce as uneven-aged stand that consists of many small, irregularly shaped, even-aged groups (Marquis, 1989). Expressed another way, patch cutting allows for the even-aged development of small groups within an uneven-aged forest matrix. It combines the biological advantages of clearcutting, by creating larger openings, with the aesthetic, wildlife, and market advantages of group selection, by always retaining a substantial number of large trees in the stand. Consequently, patch cutting, though difficult to implement, is becoming increasingly common in bottomland hardwood forests across the South.

The key the successful use of patch cutting is to match the size of the opening to reproductive requirements of the desired species to be regenerated, and then to cut all stems within the selected opening. To successfully regenerate Nuttall oak through the patch cutting technique, Johnson and Krinard (1989) recommended openings of at least 90 m in diameter. Openings smaller than that would not provide enough sunlight to Nuttall oak seedlings to allow them to develop into overstory trees, and would eventually become dominated by more shade-tolerant species.

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SUMMARY

Silvicultural systems integrate both regeneration and intermediate operations into an orderly process for managing forest stands. The clearcutting method of regeneration favors the development of species moderately tolerant to intolerant of shading in the seedling stages. Clearcutting is the most proven and widely used method of successfully regenerating high value species of oaks (*Quercus* spp.) In bottomland hardwood forests in the southern USA. Shelterwood methods can provide for the development of heavy-deeded species, but has produced variable results with bottomland oaks. The seed-tree method of regeneration favors light-seeded species which, except for green ash (*Fraxinus pennsylvanica*), are or low value for commodity production. The single-tree method of selection favors the development of shade-tolerant species and when applied repeatedly, causes a shift to lower value species. Group selection creates only development of shade-intolerant bottomland species. Patch cutting, a combination of uneven-aged (group selection) and even-aged (clearcutting) silviculture, creates larger openings and has been used successfully to produce an uneven-aged stand that consists of many, small, irregularly shaped, even-aged groups. Specific recommendations for the selection of silvicultural systems are presented for the eight most important species groups found in southern bottomland hardwood forests.

Table 1. Expected regeneration under different silvicultural systems for eight important southern bottomland hardwood species associations (from Johnson 1981).

Species Association	Silvicultural System	Species Usually Favored
Cottonwood	Seed tree with site preparation	Cottonwood
	Clearcut	Sycamore, sweet pecan, green ash, boxelder
Black willow	Seed tree with site preparation	Black willow
	Clearcut	Sugarberry, green ash, baldcypress,American elm, overcup oak, bitter pecan, Nuttall oak
Cypress-water tupelo	Group selection	Baldcypress, water tupelo, and sometimes green ash, overcup oak, bitter pecan
	Clearcut	Baldcypress, water tupelo, and sometimes green ash, overcup oak, bitter pecan, or elm and maple
Elm-sycamore-pecan-sugarberry	Group selection	Sweetgum, red oaks, sycamore,sweet pecan, sugarberry, green as
	Clearcut	Same as above
Elm-ash-sugarberry	Clearcut	Elm, green ash, sugarberry, Nuttall oak, willow oak
	Group selection	Same as above
Sweetgum-red oak	Group selection	Sweetgum, red oaks, green ash
	Clearcut	Heavy to sweetgum, but also red oaks, green ash
	Shelterwood	Red oaks, sweetgum, green ash
Red oak-white oak mixed species	Shelterwood	Red oaks, white oaks, Hickory,green ash, sweetgum, American hornbeam
	Group selection	Same as above
Overcup oak-bitter	Group selection	Overcup oak, bitter pecan
	Shelterwood	Overcup oak, bitter pecan, Nuttall oak, green ash